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(54) Title: A RECEPTION METHOD, AND A RECEIVER

(57) Abstract

A reception method and a receiver in a cellular radio system, the receiver comprising means (23) for measuring the power level of each received signal. To detect the received signal in an advantageous manner, the receiver of the invention comprises means (26) for dividing the received signals into several groups having at least two signals each, and means (30, 35, 40) for detecting the signals in each group from the received transmission simultaneously.

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A reception method, and a receiver

The invention relates to a reception method in a cellular radio system in which the receiver measures the power level of each received signal.

A central problem in designing and implementing a data transmission system is simultaneous transmission and reception of signals from several simultaneous users such that the signals interfere with one another as little as possible. Because of this and the transmission capacity used, various transmission protocols and multiple access methods have been used, the most common especially in mobile phone traffic being FDMA and TDMA, and recently CDMA also.

CDMA is a multiple access method based on a spread spectrum technique, and it has been recently put into use in cellular radio systems in addition to previously used FDMA and TDMA. CDMA has many advantages over the prior methods, such as simplicity of frequency planning, and spectrum efficiency.

In a CDMA method, a narrow-band data signal of a user is multiplied to a relatively broad band by a spreading code having a much broader band than the data signal. Band widths used in known test systems include e.g. 1.25 MHz, 10 MHz and 25 MHz. The multiplication spreads the data signal over the entire band to be used. All the users transmit simultaneously on the same frequency band. On each connection between a base station and a mobile station is used a different spreading code, and the signals of the users can be distinguished from one another in the receivers on the basis of the spreading code of the user. If possible, the spreading codes are selected in such a way that they are mutually orthogonal, i.e. they do not correlate with one another.

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Correlators in conventionally implemented CDMA receivers are synchronized with a desired signal, which they recognize on the basis of the spreading code. In the receiver the data signal is restored to the original band by multiplying it by the same spreading code as in the transmission step. Ideally, the signals that have been multiplied by some other spreading code do not correlate and are not restored to the narrow band. In view of the desired signal, they thus appear as noise. The object is to detect the signal of the desired user from among a number of interfering signals. In practice, the spreading codes correlate, and the signals of the other users make it more difficult to detect the desired signal by distorting the received signal. This interference caused by the users to one another is called multiple access interference.

In a data transmission method in which a TDMA multiple access method is applied are used several frequencies, each frequency being divided into time slots in which the signals of the different users are placed. Each user is thus assigned a time slot of its own. Since the frequency band reserved for the system is usually limited, the frequencies used must be repeated in the cells located at a certain distance. To achieve high frequency efficiency, the distance must be held as short as possible. It follows from this that transmissions sent at the same frequencies interfere with one another. In a certain time slot, not only the desired signal but also a noise signal is heard in the receiver, the noise signal being caused by some other connection using the same frequency.

The one-frequency detection method described above in connection with CDMA is not optimal, since the information contained in the signals of the other users is not taken into account in the detection. In addition,

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conventional detection cannot correct errors caused by partly non-orthogonal spreading codes and distortion of the signal over the radio path. In an optimal receiver, the information contained in the signals of all the users is taken into account, so the signals can be detected optimally using e.g. a Viterbi algorithm. The advantage of this detection method e.g. in a CDMA system is that the situation in the receiver resembles a one-user CDMA system where there is no multiple access interference. For example, a near-far problem, which is typical of CDMA systems, does not arise. A near-far problem is a situation where the transmission from a transmitter close to the receiver blankets the more distant transmitters. The major drawback of the Viterbi algorithm is that the calculating efficiency that it requires increases exponentially as the number of the users rises. For example, with QPSK modulation, a ten-user system with a bit rate of 100 kbit/s would require 105 million operations per second in calculating the Viterbi algorithm. In practice, this makes it impossible to implement an optimal receiver.

It is possible to approximate, however, to an optimal receiver by different methods. Prior art teaches various methods for simultaneous multiuser detection (MUD). The best known of such methods are linear multiuser detection, a decorrelating detector and a multistage detector. These methods are described in greater detail in Varanase, Aazhang, 'Multistage detection for asynchronous code division multiple access communications,' *IEEE Transactions on Communications, Vol. 38,* pp. 509-519, Apr 1990; Lupas, Verdu, 'Linear multiuser detectors for synchronous code-division multiple access channels,' *IEEE Transactions on Information Theory, Vol. 35,* No. 1, pp. 123-136, Jan 1989; and Lupas, Verdu, 'Near-far resistance of

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multiuser detectors in asynchronous channels,' *IEEE Transactions on Communications, Vol. 38,* Apr 1990. These methods, however, also involve many operations, such as matrix inversion operations, that require a high calculating capacity.

Another way of solving the problems caused by multiple access interference is to use interference cancellation (IC) methods. In IC-type solutions, the users are detected individually, if possible, and often in the order of magnitude, in such a way that the effect of the signals of the already detected users is cancelled from the received transmission before the next user is detected. An example for a solution of this kind is described in EP 491,668, where a procedure of the type described above is applied in a CDMA cellular radio system. Noise cancellation methods are more effective than MUD-type algorithms with respect to calculation, but their performance is lower especially in difficult reception conditions, such as in a fading multipath channel, where signals are often weak.

The object of the present invention is to provide a method in which a received signal can be detected in an advantageous manner even in the event of multiple access interference without unduly massive calculations.

This is achieved with a method of the type described in the introduction, the method being characterized in that the received signals are divided into several groups comprising at least two signals each, and that in each group the signals are detected from the received transmission simultaneously.

The invention also relates to a receiver in a cellular radio system, the receiver comprising means for measuring the power level of each received signal. The receiver of the invention is characterized by comprising

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means for dividing the received signals into several groups comprising at least two signals each, and means for detecting the signals in each group from the received transmission simultaneously.

The method of the invention makes it possible to combine the advantages of noise cancellation methods with those of simultaneous multiuser detection by a radical reduction in calculation but with little sacrifice of performance.

In the following the invention will be described in greater detail with reference to the examples of the attached drawings, wherein

fig. 1 shows an example of a cellular network where the method of the invention can be applied,

fig. 2 is a block diagram illustrating the structure of a receiver according to the invention,

fig. 3 is a block diagram illustrating the structure of a noise cancellation system of a receiver according to the invention, and

fig. 4 is a block diagram illustrating an alternative structure of a noise cancellation system of a receiver according to the invention.

The method of the invention is especially well-suited for use in a CDMA cellular radio system, but it can also be applied in a TDMA system, where co-channel interference is a problem. The invention can be applied both in a base station and a subscriber terminal. In the following the invention will be described in greater detail when applied in a base station of a CDMA cellular radio network, but the invention, however, is not limited thereto.

Fig. 1 illustrates part of a cellular radio system in which the method of the invention can be applied. In the cellular radio network, each cell comprises at least one base station 10 communicating

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with subscriber terminals 11-18 located in its area. The network concerned is here assumed to be a CDMA radio network. All the terminal equipments thus transmit at the same frequency to the base station 10, which distinguishes the transmissions of different terminal equipments from one another on the basis of the spreading codes of the terminal equipments. As stated above, the signals of the terminal equipments interfere with one another. The amount of interference can be estimated on the basis of the mutual cross-correlation levels of the signals. The power level appearing at the reception of each individual signal is measured in the receiver. The results obtained in the power measurement are utilized e.g. in power regulation.

In the method of the invention, the received signals are divided into groups, each group comprising at least two, preferably three to ten, different signals. Within a group, the signals are detected from the received transmission simultaneously by a detection algorithm provided by simultaneous multiuser detection.

In a preferred embodiment of the invention, the signals are divided into groups on the basis of preliminary power measurement of the received signal: the signals received at the highest power are placed in one group, and the signals received at lower powers are placed in other groups, so that each group comprises signals received at approximately the same power. The division is easy to carry out since the signals are measured for power anyway because of power regulation.

In another embodiment of the invention, the signals are divided into groups on the basis of mutual cross-correlation estimates. The signals that interfere with one another the most can here be placed in the same group. This is effective in view of interference cancellation, since methods for simultaneous multiuser

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detection effectively eliminate mutual correlation. This, however, requires that the received signal is subjected to cross-correlation estimation with all signals contained in the transmission. If a large number

5   of signals is received, the number of calculations needed increases considerably. One way of estimating cross-correlation between signals is to calculate a correlation estimate on the basis of the codes, code phases and channel parameters of the signals. Somewhat

10   fewer calculations are thus needed.

In the method of the invention, simultaneous detection of signals within a group can be implemented by using known algorithms. The methods for regenerating and extracting detected signals can also be selected as

15   desired. The advantage achieved with the invention is that system-specific parameters and methods can be selected according to what is suitable for a specific application, even dynamically, depending on what the load is and how reliable the estimation of the

20   parameters needed is. The best implementation in each specific case depends on the need and the resources. For example, when the number of received signals is not large, the signals can be divided into groups on the basis of cross-correlation estimates, but as the number

25   of the signals rises, it is possible to start dividing the signals on the basis of the received power. Also when the method is applied in different equipments, different algorithms can be used. Especially in radio phone applications, the noise cancellation resources and

30   needs of the base station and the subscriber terminal are very different.

In a preferred embodiment of the invention, the signal groups are detected in succession such that the group comprising signals with the highest power levels

35   is detected first. After the detection, the signals are

regenerated and extracted from the received
transmission. The interference of the already detected
signals with the other signals can thus be eliminated.
The second strongest group is then detected, and its
effect is likewise extracted from the received
transmission before the next group is detected. The same
procedure is continued, proceeding towards the weakest
group, until all the groups and signals have been
detected.

In the example of fig. 1, let the base station
10 perform the division into groups by placing
subscriber terminals 11, 13 and 15 in the first group,
terminal equipments 12, 16 and 18 in the second group,
and terminal equipments 14 and 17 in the third group.
The groups are detected in the order of magnitude,
starting with the group whose received powers give the
largest sum. Let this strongest group comprise signals
from terminal equipments 11, 13 and 15. The signals of
the group are detected simultaneously from the received
transmission by a selected algorithm. The detected
signals are then regenerated and extracted from the
received transmission. The second strongest group is
then detected, the group here being a group containing
signals from terminal equipments 11, 16 and 18. The
signals are detected from a transmission from which the
interference of the already detected signals has been
extracted. As above, the detected signals are extracted
from the received transmission, whereafter the remaining
group, which comprises signals from terminal equipments
14 and 17, is detected.

In a preferred embodiment of the invention, the
signal groups are detected in parallel. The detection
of one group is then not dependent on the detection of
another group as in the previous embodiment.

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As above, let the base station 10 in the example of fig. 1 conduct the division into groups by placing subscriber terminals 11, 13 and 15 in the first group, terminal equipments 12, 16 and 18 in the second group, and terminal equipments 14 and 17 in the third group. In another embodiment of the invention, all three signal groups are detected in parallel, independent of one another. The groups may be detected simultaneously, but this is not essential to the embodiment.

By the method of the invention, calculations needed in the detection of the received transmission can be reduced significantly. For example, to detect 15 users from the output of the matched filters, a decorrelating detector requires about 15^3 = 3375 multiplications, whereas the division into three groups requires only about $3*5^3$ = 375 multiplications, i.e. calculation needed is here reduced almost to a ninth part. With the Viterbi algorithm, even more is saved, since its complexity increases exponentially as a function of the number of users.

Fig. 2 is a block diagram illustrating the structure of a receiver according to the invention. The receiver of the invention comprises an antenna 20 by which the received signal is supplied to radio frequency parts 21. From the radio frequency parts, the signal is supplied through an A/D converter 22 to means 23, which pre-process the received transmission by conducting it to preliminary power measurement, on the basis of which the received signals can be divided into groups. The receiver also comprises means 24 for detecting the received signal. A signal 25 obtained from the detection means is supplied further to other parts of the receiver. The receiver also comprises controlling means 26, which control the operation of the above-mentioned parts.

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Fig. 3 is a block diagram illustrating in
greater detail the general structure of a detector block
of a receiver according to a preferred embodiment of the
invention. The detector block receives an input of the
5   received transmission comprising the signals of all the
received users. Let the total number of signals from the
users be N, and the signals be divided into K groups
having M signals each. In reality, the number of the
signals is not necessarily the same in every group. The
10   detector block comprises means 30 for simultaneous
detection of the signals belonging to the first group.
Detected signals 32, which thus comprise the signals of
the first M users, are supplied for further processing,
and to means 31, where the detected signals are
15   regenerated for interference cancellation. The received
transmission is supplied through a delay circuit 33 to
an adder 34, where the output of the regenerating means
31 is extracted therefrom. The interference of the
signals belonging to the first group with the other
20   signals is thus eliminated. Correspondingly, the
detector block comprises means 35 for simultaneous
detection of the signals of the second group, and means
for regenerating detected signals 37. In the second
group, the detected signal thus here comprises the
25   signals of the next M users. The receiver further
comprises adding means 39, by which the regenerated
signals are extracted from the transmission supplied to
the adder 39 through a delay circuit 38. The detector
block comprises corresponding means for detecting all
30   K groups. In a last detector 40 is detected the
remaining group; detected signals 41 belonging to this
group need not be regenerated but can be supplied for
further processing in the receiver.

Where a CDMA receiver is concerned, each
35   detector means 30, 35 and 40 comprises a RAKE receiver

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in a preferred embodiment of the invention, and filters
matched with the spreading codes of the signals to be
detected. In the receiver, the block 23 for pre-
processing the signal can be implemented in many ways.
One alternative is to utilize the matched filters of the
detector blocks at the beginning of the reception
process: the matched filters conduct preliminary power
measurement, on the basis of which a preliminary
division of the signals into groups is performed, and
after which the measurement can be specified
iteratively.

Fig. 4 is a block diagram illustrating the
general structure of a detector block of a receiver
according to another embodiment of the invention. The
detector block receives an input of a received
transmission comprising the signals of all the received
users. As above, let the total number of signals from
the users be N, and the signals be divided into K groups
having M signals each. In reality, the number of the
signals is not necessarily the same in every group. The
detector block comprises means 30, 35, 40 for detecting
signal groups. The means are connected in parallel such
that all the means receive an input of the same received
transmission. Each means detects a predetermined signal
group by detecting the signals of the group simultan-
eously. For example, let means 30 detect the first
group, means 35 the second group, and means 40 the Kth
group. Detected signals 32, which thus comprise the
signals of the first M users, are supplied for further
processing. Detected signals 37, 40 are processed in the
same manner. Since the signal groups are thus detected
in parallel, their detection is not interdependent.

Although the invention is described above with
reference to the example illustrated in the attached
drawings, it is to be understood that the invention is

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not limited thereto but can be modified in many ways
within the inventive idea disclosed in the attached
claims. The reception method of the invention can also
be used, for example, as a pre-stage in a multistage
5   receiver or a receiver of some other type.

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Claims

1. A reception method in a cellular radio system in which the receiver measures the power level of each received signal, c h a r a c t e r i z e d in that the received signals are divided into several groups comprising at least two signals each, and that in each group the signals are detected from the received transmission simultaneously.

2. The method of claim 1, c h a r a c t e r - i z e d in that each group is detected in succession, and that the signals of the already detected groups are regenerated and extracted from the received transmission before the next group is detected.

3. The method of claim 1, c h a r a c t e r - i z e d in that the groups are detected in parallel.

4. The method of claim 2, c h a r a c t e r - i z e d in that the groups are detected in succession such that the group comprising signals with the highest received power level is detected first.

5. The method of claim 1, c h a r a c t e r - i z e d in that the received signals are divided into groups on the basis of the received power level.

6. The method of claim 1, c h a r a c t e r - i z e d in that the received signals are divided into groups on the basis of mutual cross-correlation levels such that the signals that interfere with one another the most are placed in the same group.

7. The method of claim 1, c h a r a c t e r - i z e d in that the received signals are supplied by a plural number of users.

8. The method of claim 1, c h a r a c t e r - i z e d in that the received signals are supplied by one and the same user.

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9. The method of claim 1, c h a r a c t e r -
i z e d in that the cellular radio system employs a
CDMA multiple access method.

10. The method of claim 1, c h a r a c t e r -
5   i z e d in that the cellular radio system employs a
TDMA multiple access method.

11. A receiver in a cellular radio system
comprising means (23) for measuring the power level of
each received signal, c h a r a c t e r i z e d by
10   comprising means (26) for dividing the received signals
into several groups having at least two signals each,
and means (30, 35, 40) for detecting the signals in each
group from the received transmission simultaneously.

12. The receiver of claim 11, c h a r a c -
15   t e r i z e d by comprising means (30, 35, 40) for
detecting the groups in succession, means (31, 36) for
regeneration, and means (34, 39) for extracting the
signals of the already detected groups from the received
transmission before the next group is detected.

20   13. The receiver of claim 12, c h a r a c -
t e r i z e d by comprising means (30, 35, 40) for
detecting the groups in succession such that the group
comprising signals with the highest received power level
is detected first.

25   14. The receiver of claim 11, c h a r a c -
t e r i z e d by comprising means (30, 35, 40) for
detecting the groups in parallel.
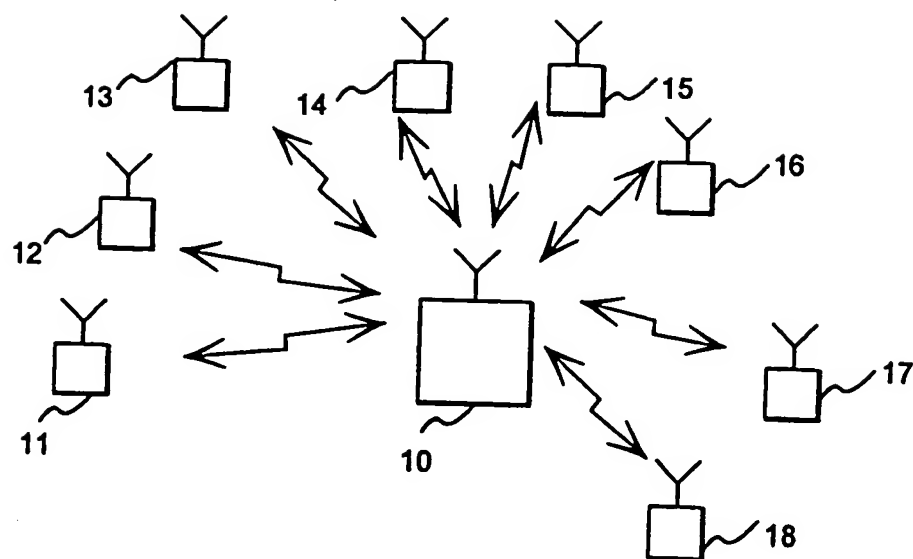
Fig. 1
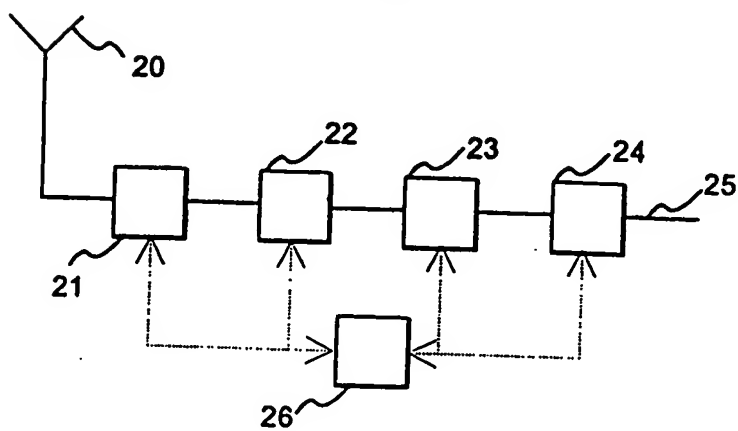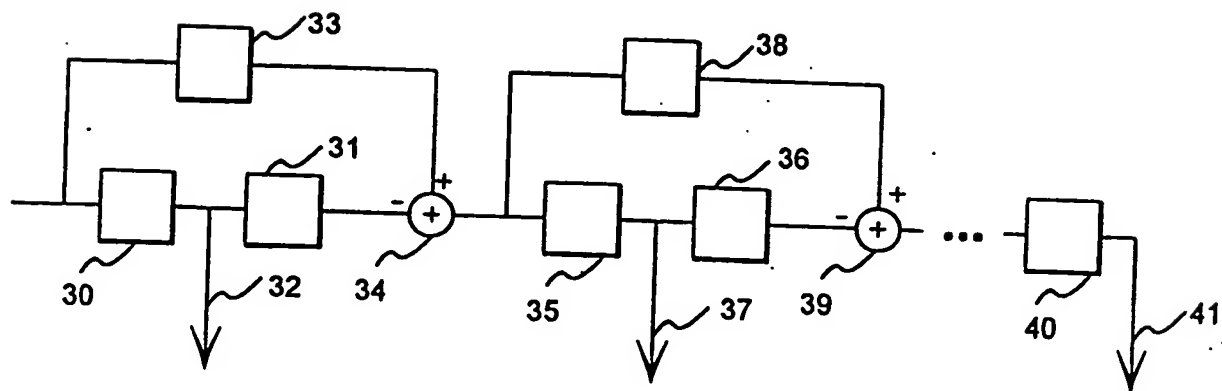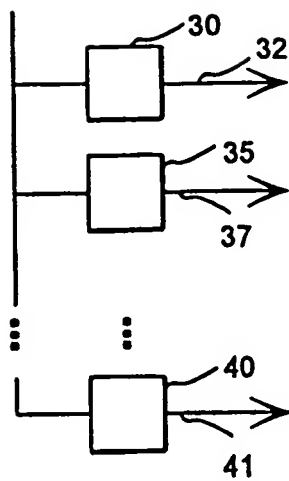
Fig. 2

Fig. 3

Fig. 4